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(71) Applicant(s)

Merck Patent GmbH

(Incorporated in the Federal Republic of Germany)

Frankfurter Strasse 250, D-64271 Darmstadt,
Federal Republic of Germany

(72) Inventor(s)

Owain Llyr Parri

Ian Bonny

Ian Victor E Hassall

Mark John Goulding

Simon Greenfield

Emma Jane Brown

David Coates

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(74) Agent and/or Address for Service

Venner Shipley & Co
20 Little Britain, LONDON, EC1A 7DH,
United Kingdom

(54) Liquid crystalline copolymer

(57) The invention relates to copolymers made from mono reactive liquid and/or di reactive liquid crystals which can be photopolymerised to form copolymers and to novel reactive liquid crystal compounds having a nematic phase. Preferably the reactive liquid crystal is polymerised while in the liquid crystal phase to produce an oriented birefringent polymer film. To do this the reactive liquid crystal, in its nematic or smectic phase is aligned (by well known techniques such as rubbed polyimide etc.) and the thin film containing a small amount of photoinitiator, is subjected to ultra-violet light whereupon it polymerises into a thin, aligned polymer film.

Some of the monomers are claimed to be novel.

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LIQUID CRYSTALLINE COPOLYMER

The invention relates to copolymers made from mono reactive liquid and/or di reactive liquid crystals which can be photopolymerised to form 5 copolymers and to novel reactive liquid crystal compounds having a nematic phase. Preferentially the reactive liquid crystal is polymerised while in the liquid crystal phase to produce an oriented birefringent polymer film. To do this the reactive liquid crystal, in its nematic or smectic phase is aligned (by well known techniques such as rubbed polyimide etc.) 10 and the thin film containing a small amount of photoinitiator, is subjected to ultra-violet light whereupon it polymerises into a thin, aligned polymer film.

Alternatively the mixture of reactive liquid crystal can be polymerised in a 15 solution of for example dichloromethane or toluene or tetrahydrofuran, using AIBN as initiator and heated for 24 hours at 30-60 °C. This produces a non aligned polymer which is less easily manipulated than the polymer film but may have other applications.

Most reactive liquid crystals presently known exhibit a high melting point 20 and a very short temperature range phase, also many are only smectic. This severely limits the use of these materials. The authors have found new materials which exhibit a relatively low melting point and wide liquid crystal phase range particularly nematic. Advantageously, these can be mixed together to produce low melting, wide range nematic reactive liquid 25 crystal mixtures. By changing the types of core group the optical properties of the film can be changed e.g. high birefringence core groups lead to films with a high birefringence. By changing the ratio of mono:di reactive groups the Tg of the system can be altered.

30 The incorporation of chiral groups into the reactive liquid crystal produces cholesteric phases. Typically this is done by the incorporation of a chiral alkyl chain but a chiral group between ring systems can also be used. By changing the amount of chiral reactive liquid crystal the pitch length of the cholesteric phase can be altered. Generally, when polymerised there is 35 very little change in pitch length. It is also possible to add non reactive materials containing a chiral group to induce a cholesteric phase.

It was therefore necessary to develop a completely new material concept in order to fulfill the requirements outlined above resp. to fulfill them to a greater extent than is the case with conventional liquid crystal polymers. Other objects of the present invention are evident for the expert from the following detailed description of the invention.

5 It was found that these objects could be achieved by the copolymers according to the present invention.

10 The invention thus relates to a liquid crystalline copolymer obtainable by copolymerization of at least one polymerizable reactive component A of formula

15 R₁-P-X-A₁-Z₁-A₂-R₂ (I)

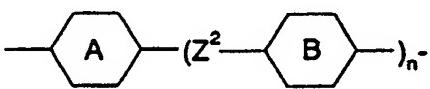
wherein

- 20 R₁ is CH₂=CW-COO-, HWC-C(=O)-, HWN-, CH₂=CH- or HS-CH₂-(CH₂)_m-COO- with W being H, Cl or alkyl with 1-5 C atoms and m being 1-7
- 25 P is alkylene with up to 12 C atoms, it being also possible for one or more non adjacent CH₂ groups to be replaced by -O-,
- 30 X is -O-, -S-, -COO-, -OCO-, -C≡C- or a single bond,
- 35 R₂ is a straight-chained, branched or chiral alkyl radical with up to 15 C atoms which is unsubstituted, mono- or polysubstituted by halogen, it being also possible for one or more CH₂ groups in these radicals to be replaced, in each case independently of one another, by -O-, -S-, -CO-, -OCO-, -CO-O- or -O-CO-O- in such a manner that oxygen atoms are not linked directly to one another, or alternatively R₂ has one of the meanings given for R₁-P-X-,

- 3 -

A¹ is a 1,4-cyclohexylene, a 1,4-phenylene in which one or two CH groups may be replaced by N or a naphthalene-2,6-diy radical which is unsubstituted or substituted by 1 to 4 halogen atoms,

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A² is 

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with  and  being  or 

it being possible for these rings to be substituted by CN or halogen and one of the 1,4-phenylene groups can also be replaced by a 1,4-phenylene radical in which one or two CH groups are replaced by N,

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and

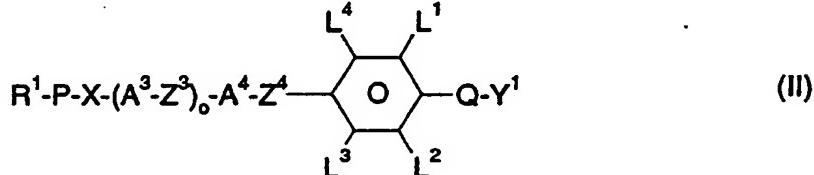
Z¹ and Z² are each independently -CO-O-, -O-CO-, -CH₂CH₂- or a single bond,

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n is 0 or 1,

and at least one polymerizable component B of formula II

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wherein R¹, P, X and the meaning give for formula I, and Q has the meaning given for formula I, and

Y¹ is -H, -F or -Cl,

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Q is -CF₃, -OCF₃, -C₂F₄, or -OC₂F₄, or a single bond, if Y¹ is F or Cl

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- A³ and A⁴ are each independently
(c) 1,4-phenylene radical in which one or two CH groups can be replaced by N,
- 5 (d) a 1,4 cyclohexylene radical in which one or two non-adjacent CH₂ groups can be replaced by -O- or -S-, or
(e) a naphthalene-2,6-diyl radical, a piperidine-1,4-diyl radical, a thiophene-2,5-diyl radical, a 1,3,4 thiadiazol-2,5-diyl radical, it being possible for radicals (c) and (d) to be substituted by CN or halogen,
- 10 Z³ is, independently of one another, -CH₂CH₂-, -COO-, -OCO-, -C≡C- or a single bond,
- 15 Z⁴ is -CH₂CH₂-, -C≡C- or a single bond,
- L¹ through L⁴ are each independently H, halogen, -CH₃, -CF₃ or -CN, preferably
- 20 H or fluorine.
- o is 0, 1 or 2, and
- 25 the groups A³ being same or different in the case that o is 2.
- The polymeric composite materials according to the present invention are being based on a liquid crystal copolymer. The liquid crystal copolymer can consist of one liquid crystal copolymer resp. oligomer or a mixture of two or more liquid crystal copolymers and/or oligomers of different
- 30 chemical composition. Mixing can be effected by solving the different liquid crystal copolymers and/or oligomers in a suitable solvent like, for example, dichloromethane (DCM), with subsequent evaporation of the solvent or by other methods.

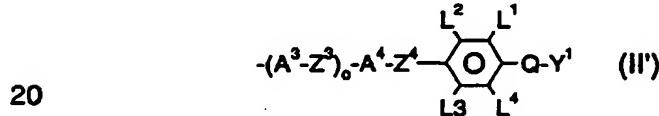
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The liquid crystal copolymers used are side chain copolymers and/or oligomers of formula A



wherein

- 10 Pm is a polymer main chain group
- SP is a bivalent spacer group,
- 15 B is an organic rod-like radical containing at least two six-membered groups, including the radicals of formula I' -A¹-Z¹-A²-R²(I') and of formula II'



<m> is the mean degree of polymerization.

- 25 Formula A is merely intended to symbolize side-chain copolymers in a relatively diagrammatic manner; thus, it is not necessary, for example, for each main-chain unit to carry a mesogenic unit, and it is also possible, for example, to use copolymers in which Pm represents various main-chain units. Furthermore, Pm or, in the case of copolymers, one or more groups Pm may be one or more mesogenic groups, so that formula I also covers combined main-chain/side-chain oligomers and polymers.

30 A good review on side-chain polymers and processes for their preparation is given by H. Finkelmann in Thermotropic Liquid Crystals, ed. by G.W. Gray, Chichester 1987, p. 159 ff, which describe the preparation of side chain polymers by 'solution polymerisation'.

If a mixture of 2 or more liquid-crystalline oligomers and/or polymers is used, $\langle m \rangle$ is the arithmetic mean of the mean degrees of the mean degrees of polymerization of the various components of the polymer phase.

5

Liquid-crystalline copolymers may be liquid-crystalline or not; in case they are liquid-crystalline they may have various phases, a correlation frequently being observed for side-chain polymers containing mesogenic groups B which are not too polar between the phase sequence of the corresponding low-molecularweight compounds B and that of the side-chain polymers (see Thermotropic Liquid Crystals, ed. by G.W. Gray, Chichester 1987, p. 164). Liquid-crystalline polymers and in particular side-chain polymers having a nematic and/or smectic phase and further particularly having a nematic phase are preferred, the terms nematic and smectic being broadly drawn and also covering cholesteric-nematic and cholesteric-smectic phases having a helical structure.

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Suitable polymeric backbones $\text{--}(\text{Pm})\text{--}$ are in principal all polymers whose chains have a certain flexibility. These may be linear, branched or cyclic polymer chains. The degree of polymerization is normally at least 10 and in particular at least 15; however, oligomers containing 3 to 15 monomer units are also possible.

25

The polymers obtainable by solution polymerization show as a rule a degree of polymerization of 10-100. The polymers obtainable by in situ photopolymerization, which are a preferred embodiment of this invention exhibit as a rule a degree of polymerization which is higher than 100, preferably higher than 400, in particular higher than 500.

30

Preference is given to polymers containing C-C main chains, in particular polyacrylates, polymethacrylates, poly- α -halo-acrylates, poly- α -cyanoacrylates, polyacrylamides, polyacrylonitriles or polymethylene malonates. Further preference is also given to polyesters, polyamides, polyimides, polyphophazenes, polyurethanes, and, in particular, to polysiloxanes.

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Suitable spacers are in particular linear or branched alkylene groups having 1-12 and, in particular, 1-8 carbon atoms, in which, in addition, one or more non-adjacent CH₂ groups may be replaced by -O-, -S-, -O-CO-, -CO-O-, -CH-, or -C≡C-.

5

Examples of suitable spacers are the following groups: ethylene, propylene, butylene, pentylene, hexylene, heptylene, octylene, nonylene, decylene, undecylene, dodecylene, octadecylene, ethyleneoxyethylene, methyleneoxybutylene, ethylene-thioethylene, ethylene-N-methyliminoethylene and 1-methyl- alkylene.

10

The rod-like mesogenic groups are generally low-molecular-weight liquid-crystalline radicals which are bonded terminally or laterally to the polymer chain via sufficiently flexible spacers. In the case of terminal linking, which is generally preferred, these radicals are able to rotate about the molecular long axis and therefore have cylindrical symmetry.

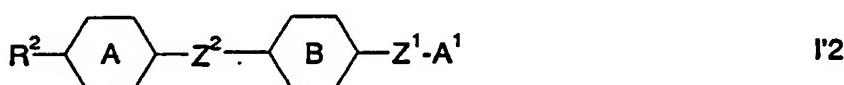
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The formula I' covers the bicyclic and tricyclic radicals of the sub-formulae I'1 - I'2:

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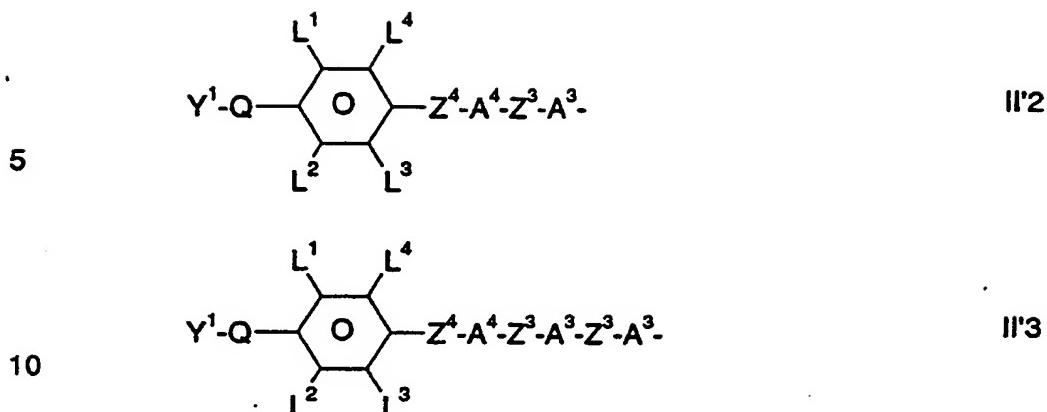


The formula II' covers bicyclic, tricyclic and tetracyclic radicals of the sub-formulae II'1 - II'3.

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15 In the mesogenic radicals of the formula I', R₂ is preferably an alkyl or alkenyl radical which is unsubstituted or substituted by at least one halogen atom, it being possible for one or two non-adjacent CH₂ groups of these radicals to be replaced by O atoms and/or by -O-CO-, -CO-O- and/or -O-CO-Ogroups.

Y¹ is preferably F or Cl.

Furthermore, the mesogenic radicals of the formula II' in which Q-Y is F or Cl are preferred.

If R₂ is an alkyl radical or alkoxy radical, this may be straight-chain or branched. It is preferably straight-chain, has 2, 3, 4, 5, 6, 7 or 8 carbon atoms and accordingly is preferably ethyl, propyl, butyl, pentyl, hexyl, heptyl, octyl, ethoxy, propoxy, butoxy, pentoxy, hexoxy, heptoxy or octoxy, furthermore methyl, nonyl, decyl, undecyl, dodecyl, tridecyl, tetradecyl, pentadecyl, methoxy, nonoxy, decoxy, undecoxy, dodecaxy, tridecoxy or tetradecoxy.

35 Oxaalkyl is preferably straight-chain 2-oxapropyl (= methoxymethyl), 2-(= ethoxymethyl) or 3-oxabutyl (= 2-methoxyethyl), 2-, 3- or 4-oxapentyl, 2-, 3-, 4- or 5-oxahexyl, 2-, 3-, 4-, 5- or 6-oxaheptyl, 2-, 3-, 4-, 5-, 6- or 7-oxaoctyl, 2-, 3-, 4-, 5-, 6-, 7- or 8-oxanonyl, or 2-, 3-, 4-, 5-, 6-, 7-, 8- or 9-oxodecyl.

- 9 -

If R² is an alkenyl radical, this may be straight-chain or branched. It is preferably straight-chain and has 2 to 20 carbon atoms. Accordingly, it is particularly vinyl, prop-1- or -2-enyl, but -1-, -2- or -3-enyl, pent-1-, -2-, -3- or -4-enyl, hex-1-, -2-, -3-, -4- or -5-enyl, hept-1-, -2-, -3-, -4-, -5- or -6-enyl, oct-1-, -2-, -3-, -4-, -5-, -6- or 7-enyl, non-1-, -2-, -3-, -4-, -5-, -6-, -7- or -8-enyl, or dec-1-, -2-, -3-, -4-, -5-, -6-, -7-, -8- or -9-enyl.

Mesogenic radicals of the formula I' containing a branched wing group R¹ may occasionally be of importance as comonomers, for example due to a reduction in the tendency towards crystallization. Branched groups of this type generally contain not more than one chain branch. Preferred branched radicals R¹ are isopropyl, 2-butyl (= 1-methylpropyl), isobutyl (= methylpropyl), 2-methylbutyl, isopentyl (= 3-methylbutyl), 2-methylpentyl, 3-methylpentyl, 2-ethylhexyl, 2-propylpentyl, 2-octyl, isoprpoxy, 2-methylpropoxy, 2-methylbutoxy, 3-methylbutoxy, 2-methylpentoxy, 3-methylpentoxy, 2-ethylhexoxy, 1-methylhexoxy, 2-octyloxy, 2-oxa-3-methylbutyl, 3-cxa-4-methylpentyl, 4-methylhexyl, 2-nonyl, 2-decyl, 2-dodecyl, 6-methoxyoctoxy, 6-methyloctanoyloxy, 5-methylheptyl-oxycarbonyl, 2-methylbutyryloxy, 3-methylvaleryloxy, 4-methylhexanoxyloxy, 2-chloropropionyloxy, 2-chloro-3-methylvaleryloxy, 2-methyl-3-oxapentyl and 2-methyl-3-oxahexyl.

Bicyclic, tricyclic and tetracyclic mesogenic radicals are preferred. Furthermore preferred are radicals which contain not more than one piperidine-1,4-diyl group or naphthalene-2,6-diyl group.

Of the mesogenic radicals of the formulae I' and II' which contain a heterocyclic groups, those containing a pyridine-2,5-diyl group, pyridazine-2,5-diyl group, pyrimidine-2,5-diyl group or piperidine-1,4-diyl group are particularly preferred.

A smaller group of particularly preferred mesogenic radicals of the formulae I', I'2, II'1 and II'2 are listed below. For reasons of simplicity, Cyc denotes a 1,4-cyclohexylene group, Dio denotes a dioxane-2,5-diyl group,

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- Cy denotes a 1,4-cyclohexylene group in which, in addition, one or two adjacent CH₂ groups may be replaced by -O-, Phe denotes a 1,4-phenylene group in which, in addition, one or more CH groups may be replaced by N, PheX denotes a 1,4-phenylene group which is monosubstituted or disubstituted by F, Cl and/or CH₃, Pip denotes a piperidine-1,4-diyl group and Nap denotes a naphtalene-2,6-diyl group.
- 5

Particularly preferred mesogenic radicals of the sub-formula I'1 are those of the sub-formulae I' 1-1 to I' 1-8:

10

R ² -Cyc-Z ¹ -Cyc-	I' 1-1
R ² -Phe-Z ¹ -Phe-	I' 1-2
R ² -Phe-Z ¹ -PheX-	I' 1-3
R ² -Phe-Z ¹ -Cyc-	I' 1-4
15 R ² -Cyc-Z ¹ -Phe-	I' 1-5
R ² -Cyc-Z ¹ -PheX-	I' 1-6
R ² -Cyc-Z ¹ -PheX-	I' 1-7
R ² -PheX-Z ¹ -Phe-	I' 1-8

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In the compounds of the sub-formulae I' 1-1 to I' 1-8, R² is very particularly preferably an alkyl or alkenyl group, furthermore alkoxy or alkanoyloxy, in each case having 1-13 carbon atoms. Furthermore, Z² in these compounds is very particularly preferably an ester group (-CO-O- or -O-CO-), -CH₂CH₂- or a single bond.

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Particularly preferred mesogenic radicals of the sub-formula I'2 are those of the sub-formulae I' 2-1 to I' 2-16:

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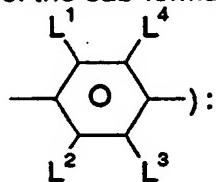
R ² -Phe-Z ² -Phe-Z ² -Phe-	I' 2-1
R ² -PheX-Z ² -Phe-Z ² -Phe-	I' 2-2
R ² -Phe-Z ² -Phe-Z ² -PheX-	I' 2-3
R ² -Cyc-Z ² -Cyc-Z ² -Cyc-	I' 2-4
R ² -Cyc-Z ² -Phe-Z ² -Phe-	I' 2-5
R ² -Cyc-Z ² -Cyc-Z ² -Phe-	I' 2-6
35 R ² -Cyc-Z ² -Cyc-Z ² -Dio-	I' 2-7
R ² -Cyc-Z ² -Phe-Z ² -PheX-	I' 2-8

- 11 -

	R ₂ -Cyc-Z ₂ -Cyc-Z ₂ -PheX-	I' 2-9
	R ₂ -Nap-Z ₂ -Cyc-Z ₂ -Phe-	I' 2-10
	R ₂ -Cy-Z ₂ -Phe-Z ₂ -Phe-	I' 2-11
	R ₂ -Nap-Z ₂ -Cyc-Z ₂ -Cyc-	I' 2-12
5	R ₂ -Phe-Z ₂ -Cyc-Z ₂ -Cyc-	I' 2-13
	R ₂ -Cyc-Z ₂ -Phe-Z ₂ -Cyc-	I' 2-14
	R ₂ -Cyc-Z ₂ -PheX-Z ₂ -Cyc-	I' 2-15

10 Of the compounds of the sub-formulae I' 2-1 to I' 2-16 which contain a 1,4-phenylene group in which one or two CH₂ groups have been replaced by N, those containing a pyridine-2,5-diyl group or pyrimidine-2,5-diyl group are very particularly preferred.

15 Particularly preferred mesogenic radicals of the sub-formula II'1 are those of the sub-formulae II' 1-1 to II' 1-6 (PheL denotes a group of formula



	Y ₁ -Q-PheL-Z ₄ -Phe-	II' 1-1
	Y ₁ -Q-PheL-Z ₄ -Cyc-	II' 1-2
	Y ₁ -Q-PheL-Z ₄ -PheX-	II' 1-3
25	Y ₁ -Q-PheL-Z ₄ -Dio-	II' 1-4
	Y ₁ -Q-PheL-Z ₄ -Pip-	II' 1-5
	Y ₁ -Q-PheL-Z ₄ -Nap-	II' 1-6

30 Particular preferred mesogenic radicals of sub-formula II'2 are those of the sub-formulae II' 2-1 to II' 2-9:

	Y ₁ -Q-PheL-Z ₄ -Phe-Z ₃ -Phe-	II' 2-1
	Y ₁ -Q-PheL-Z ₄ -Phe-Z ₃ -Cyc-	II' 2-2
	Y ₁ -Q-PheL-Z ₄ -Cyc-Z ₃ -Cyc-	II' 2-3
35	Y ₁ -Q-PheL-Z ₄ -PheX-Z ₃ -Phe-	II' 2-4
	Y ₁ -Q-PheL-Z ₄ -PheX-Z ₃ -Cyc-	II' 2-5
	Y ₁ -Q-PheL-Z ₄ -PheX-Z ₃ -PheX-	II' 2-6

Y1-Q-PheL-Z ⁴ -Phe-Z ³ -PheX-	II' 2-7
Y1-Q-PheL-Z ⁴ -Phe-Z ³ -Nap-	II' 2-8
Y1-Q-PheL-Z ⁴ -PheX-Z ³ -Nap-	II' 2-9

- 5 In the compounds of the sub-formulae II' 2-1 to II' 2-9, at least one of the two groups Z⁴ and Z³ is very particularly preferably a single bond or CH₂CH₂ and the other is preferably also a single bond or -CO-O- or -O-CO-.
- 10 Liquid-crystalline side-chain polymers are prepared by polymerization processes which are known per se and are described in the literature (for example in the standard works such as Oelian, Principles of Polymerization, McGraw-Hill, New York), to be precise under reaction conditions which are known and suitable for the reactions. Use may also be made here of variants which are known per se, but are not described here in greater detail.
- 20 Obtaining a liquid crystal copolymer with a sufficiently high glass transition temperature is routine work for the expert, and does not require any inventive effort, in particular in case the liquid crystal copolymer is being based on side chain polymers and/or oligomers according to formulae I and II. It is, for example, well known among experts that the glass transition temperature of liquid crystalline polymers and/or oligomers can be increased if the length of the spacer is chosen to be rather short, for example, as C₂-C₆ and, in particular, C₂-C₄, and/or if a rather "stiff" polymer backbone like, for example, a polymethacrylate, or a poly- α -haloacrylate is used. The glass transition temperature of the liquid crystal polymer component can also be increased by adding a high-T_G liquid crystal polymer to a given base mixture.
- 30 The copolymer preferably exhibits a nematic, cholesteric or smectic phase; the clearing point is preferably somewhat higher than the glass temperature, in particular, 5-25 °C, in order to have a sufficient temperature range of processing. Outside the temperature range of processing, the mixture can be liquid-crystalline or not liquid-crystalline.
- 35

- It is usually sufficient if one of the liquid crystal copolymer components exhibits one or more liquid crystal states, in particular in the temperature range of processing since it was frequently observed that the reactive liquid crystalline component induces a liquid crystalline phase in the
- 5 resulting mixture. Mixtures wherein both the liquid crystal copolymer components exhibit one or more liquid crystalline states are particularly preferred while mixtures wherein none of these components is liquid-crystalline, are usually less preferred.
- 10 In the case where the copolymer is formed in solution, it could be used by dissolving in a suitable solvent e.g. toluene and coating onto a substrate (with no alignment layer). Upon evaporation of the solvent and subsequent heating to the isotropic phase of the copolymer, followed by slow cooling, a scattering texture is produced. For this to occur the copolymer must have
- 15 a clearing point > 10 °C above Tg which ideally should be above ambient temperature. If a suitable dye is incorporated into the copolymer film the film can be locally heated into the isotropic liquid (written on) using a laser beam. On fast cooling the written areas remain 'clear' and the clear state is locked in by cooling by Tg. Such devices exhibit permanent storage etc.
- 20 The copolymers obtained are especially useful for permanent data storage. Verbal information, symbols, diagrams etc. can be written in by heating the desired parts of the composite material with a finely focussed laser beam or other heat sources to temperatures above the glass
- 25 transition resp. clearing temperature thus rendering the composite material transparent. The transparent state can be maintained by rapidly cooling the composite material below the glass transition temperature of the composite material, and the information is depicted in form of transparent characters, symbols etc. on a scattering background.
- 30 Heating should be effected rather rapidly in order to avoid dissipation of the thermal energy; heating with laser energy therefore is usually especially preferred. The composite materials according to the present
- 35

invention sometimes exhibits no precise clearing temperature but the become progressively clearer in a temperature range of, for example, 10-20 °C, and the maximum temperature is preferably adjusted in such a way that a high transparency and thus a high contrast is obtained.

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Subsequently, the material is cooled below the glass transition temperature with a high cooling rate in order to avoid restoration of the scattering state; the cooling rate preferably is not less than 20 K/min and, in particular, more than 40 K/min; these values are, however, thought to be only illustrative and by no means limitative.

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The copolymer can preferably be used, for example, as master-fiche in card-indices, as permanent overhead sheet etc. and is thus of enormous economic importance.

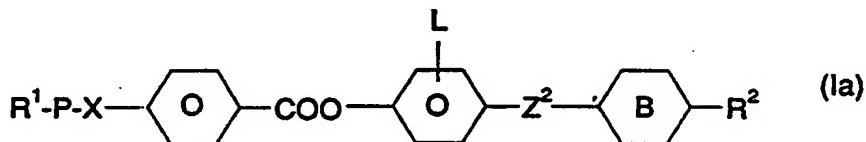
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The polymerizable reactive components A and B are partly known and partly novel. thus the invention relates to novel polymerizable, reactive liquid crystal compound of formulae I or II in particular, wherein X is -C≡C-.

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Furthermore the invention relates to polymerizable, reactive liquid crystal compound of formula Ia

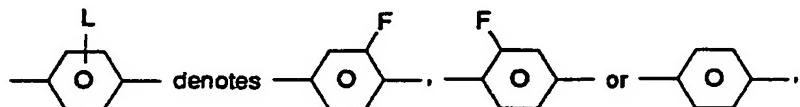
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wherein R¹, R², P, -B- and X have the meaning given, and

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Z² is -CH₂CH₂- or a single bond, preferably -CH₂CH₂

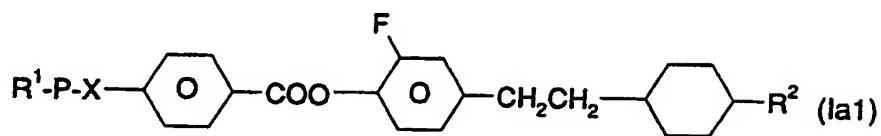


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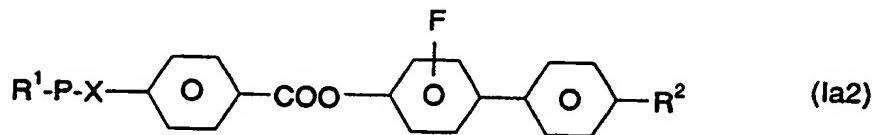
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in particular compounds of formula Ia1 and Ia2:

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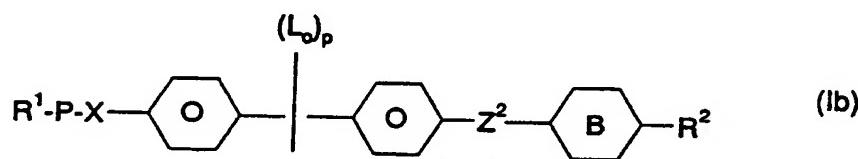


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and of formula Ib

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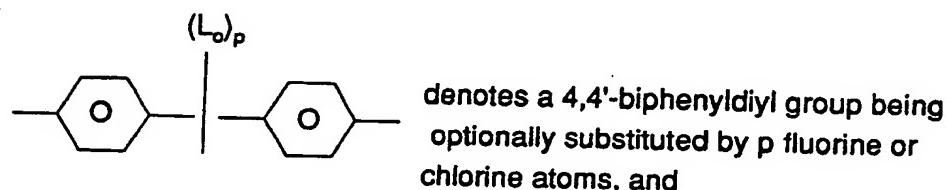


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wherein R^1 , R^2 , P , $\text{---}\text{B}\text{---}$ and X have the meaning given, and

Z^2 is $-\text{CH}_2\text{CH}_2-$ or a single bond, or in the case that L_0 is Cl Z^2 denotes also $-\text{O}-\text{CO}-$

25



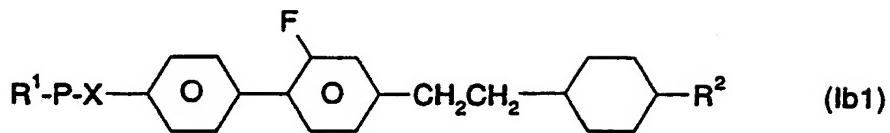
30

p is 0 or an integer between 1 and 4

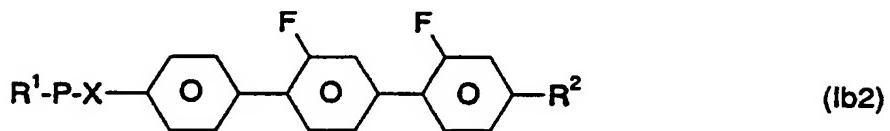
35

in particular of formulae Ib1 and Ib2

5



10



Preferred embodiments of the invention are:

15

a) polymerizable reactive liquid crystal compounds wherein R² is achiral;

20C

b) polymerizable reactive liquid crystal compound of formula II,
wherein

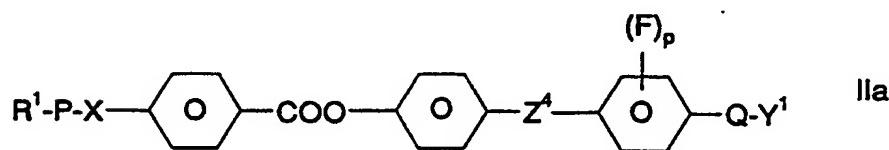
20

Q-Y¹ is F, Cl, -OCF₃, -OCF₂H, -CF₃ or OC₂F₅, in particular
F or Cl;

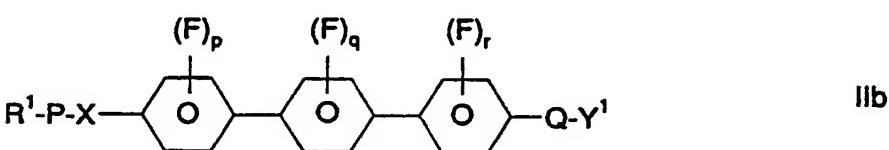
25

c) polymerizable reactive liquid crystal compounds of formulae IIIa
or IIIb

30



35



wherein R¹, P, X, Q, Y¹ and p have the meaning given,

Z⁴ is -CH₂CH₂ of a single bond, and q and r are each independently 0 or an integer selected from 0 to 4;

5 d) polymerizable reactive liquid crystal compounds of formula I, wherein

X is -C≡C-,

10 or of formulae Ia and Ib, of formula II, wherein

Q-Y¹ is F, Cl, OCF₃, -OCF₂H, -CF₃, -OC₂F₅,

of formula IIb wherein

15 R¹ is CH₂=CW-COO-

with W being H, Cl or CH₃.

20 A further aspect of the invention are liquid crystalline polymers obtainable by polymerization of at least one of the inventive polymerizable reactive liquid crystal compounds.

25 A further aspect of the invention are liquid crystalline polymers obtainable by substance photo-polymerization of at least one polymerizable reactive liquid crystal compound of formulae I or II, in the presence of a photo-initiator, at least one of said reactive liquid crystal compounds being oriented in its liquid crystalline phase, preferably in its nematic phase.

30 Liquid crystalline (co-)polymers obtainable by polymerization in the presence of a plastificiser, in particular a dialkylphthalate, or a chiral dopant, in particular a chiral cyanobiphenyl or phenyl benzoate, a menthol or lactic acid derivative, are preferred.

35 The invention relates to the use of a liquid crystalline (co)polymer according to the invention in the field of integrated optics, opto-electronic and/or information storage.

These reactive liquid crystals (RLC) can be used for either of two main uses:

- 5 1) Conversion into side chain liquid crystalline polymers (SCLCP) in solution.
- 2) In-situ photopolymerisation of the RLC when oriented in their liquid crystalline phase.

10 Conversion into SCLCP

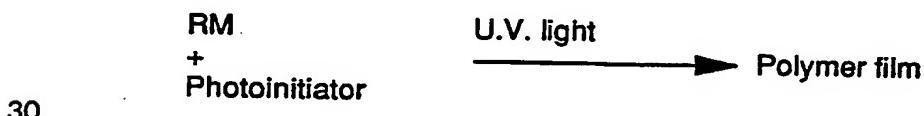
The RLC may be dissolved in a suitable solvent and the polymerisation initiated. This may be done with various initiator depending on the nature of the reactive group.

- 15 For example, when the reactive group is an acrylate, radical polymerisation initiated thermally may be used to obtain the polymer.

20 Reference: C.B. McArdle in "Side chain liquid crystalline polymers" (1989)
Blackie & Son Ltd ISBN 0-216-92503-7

In-situ photopolymerisation

- 25 In this instance, the monomers are heated to their LC phase, aligned on a substrate and subsequently photopolymerised whilst still in the aligned LC phase. This gives an anisotropic polymer film.

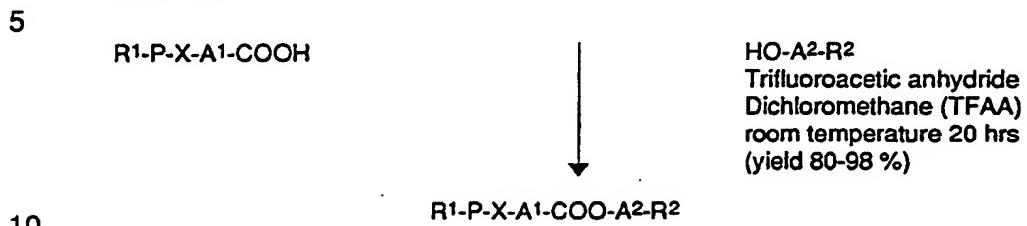


D.J. Broer, "In-Situ Photopolymerisation of Oriented Liquid Crystalline Acrylates" (1990)

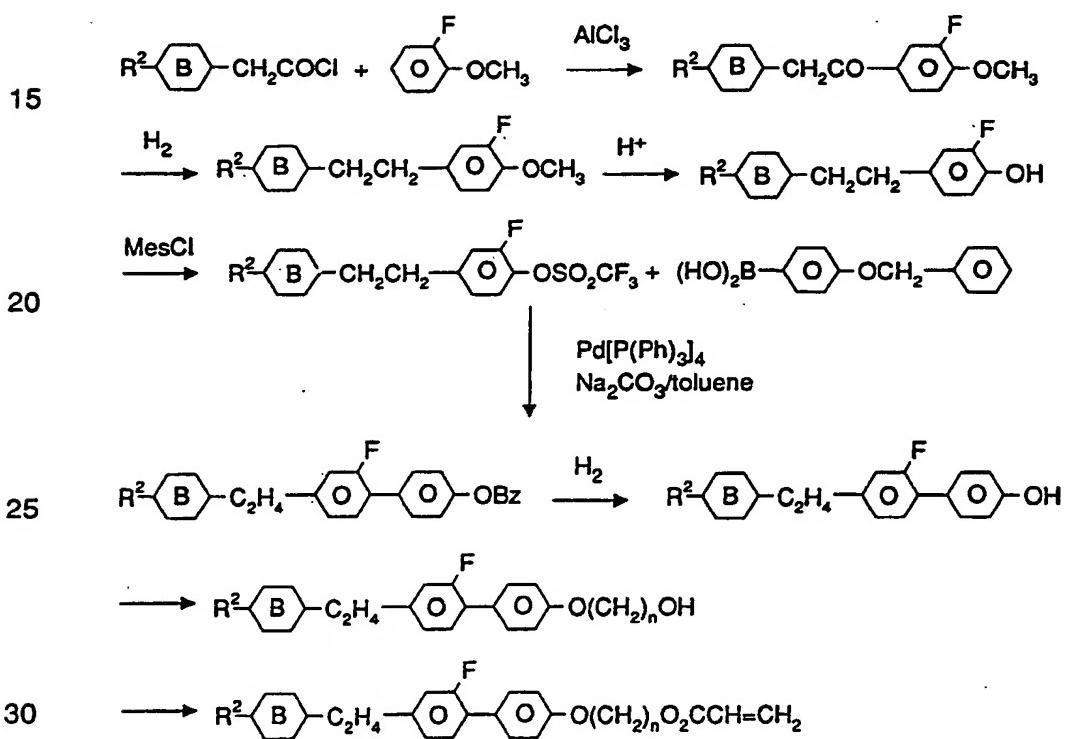
- 35 D.J. Broer, Die Angewandte Makromolekulare Chemie (1990), 183 45.
These oriented polymers may be used for several passive and active optical components: (EP 0 397 263), (EP 0 428 213) or (EP 0 451 905).

The inventive reactive compounds can be made according to the following reaction schemes:

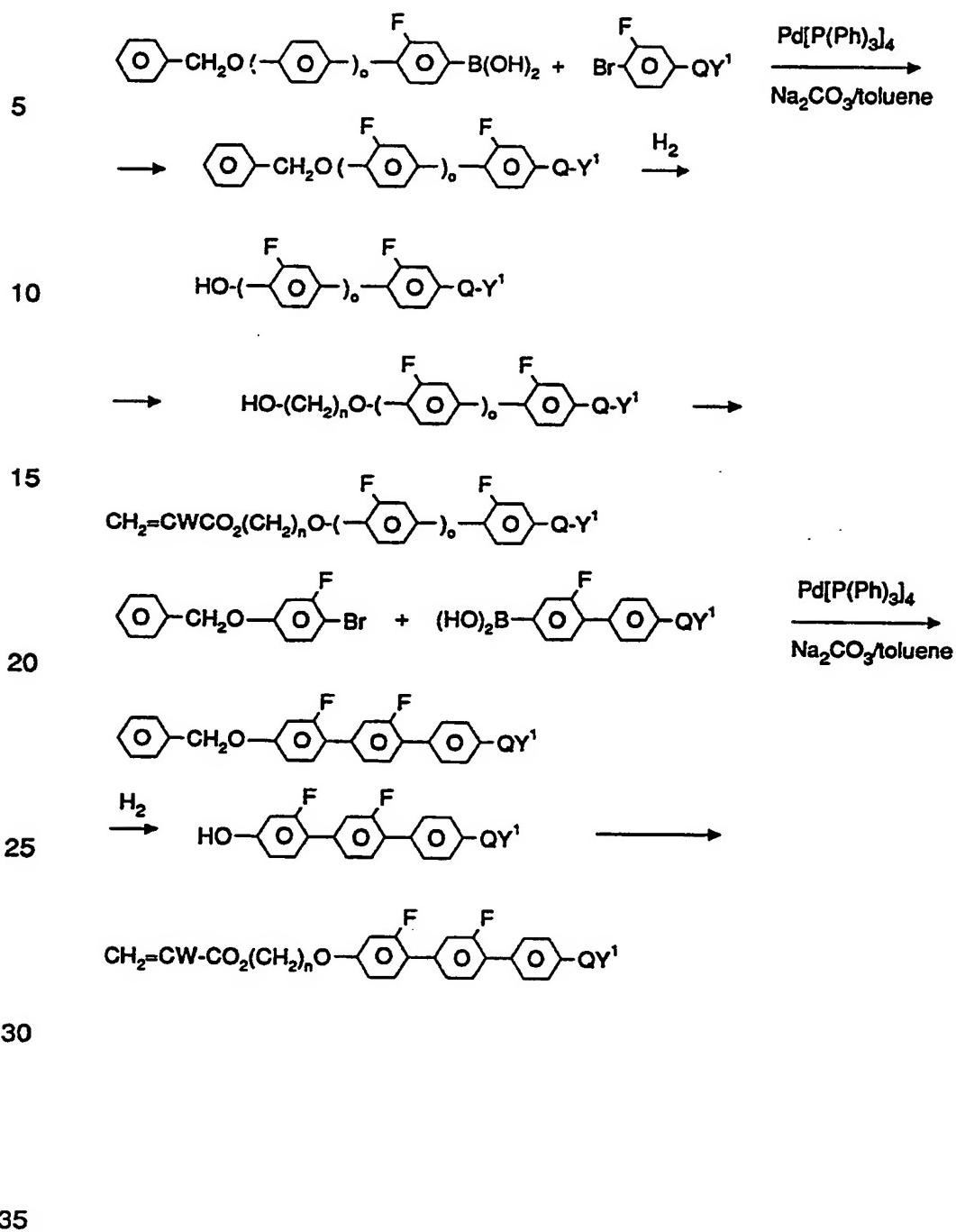
Scheme 1

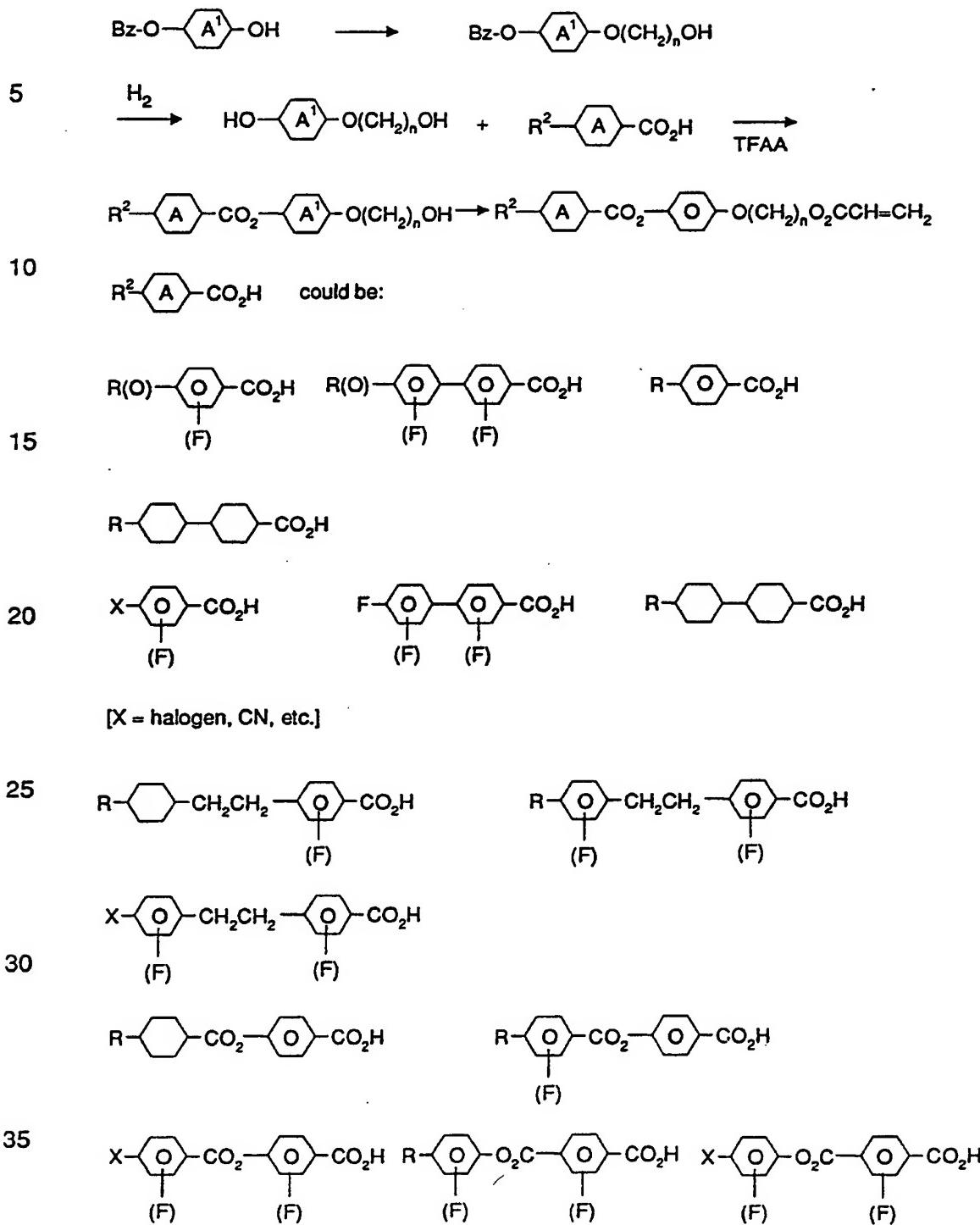


Scheme 2

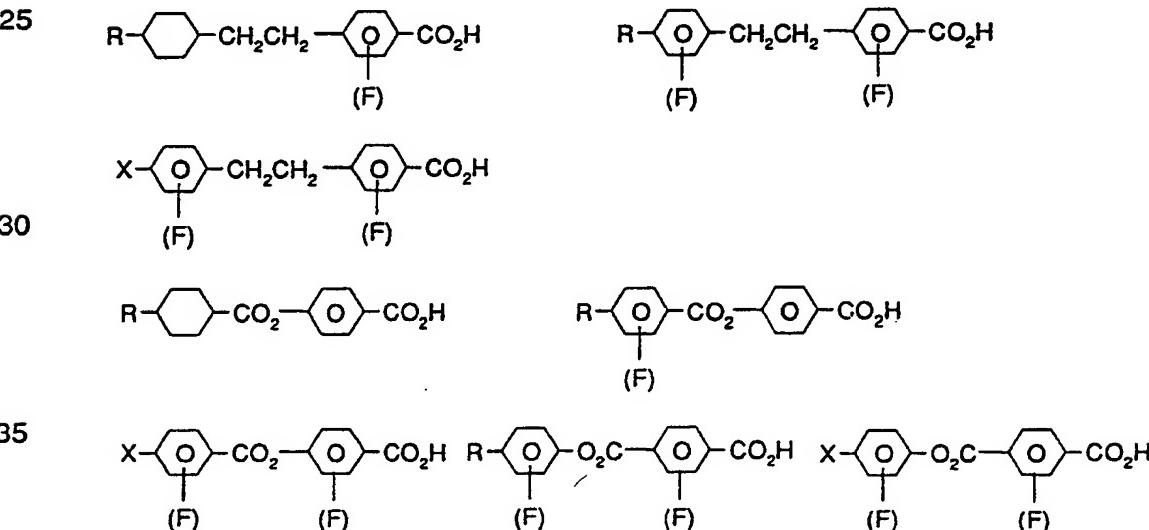


- 20 -

Scheme 3

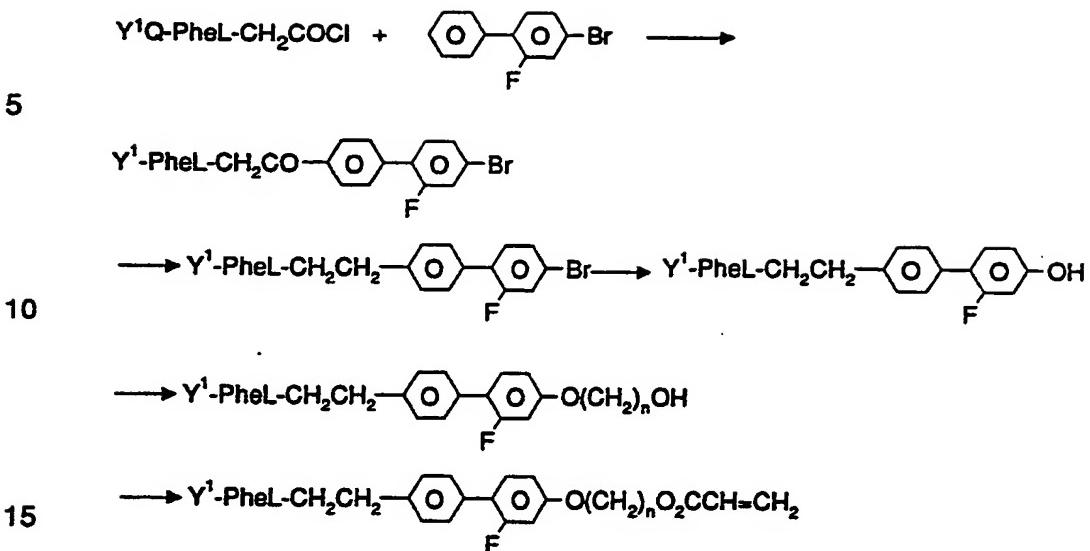
Scheme 4

[X = halogen, CN, etc.]

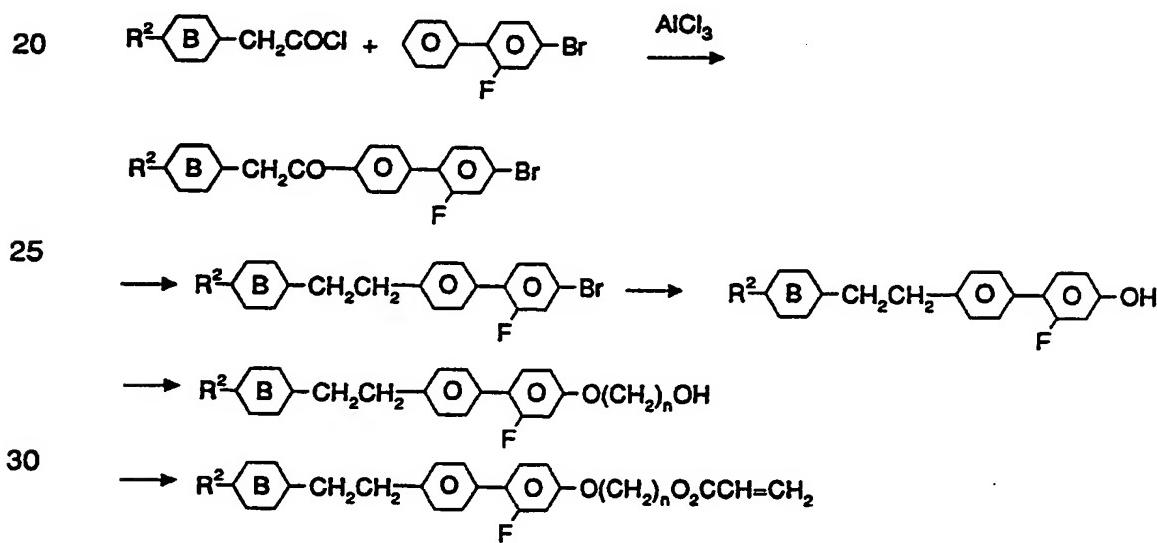


R is alkyl with up to 18 C-atoms, Bz is benzyl, (F) denotes an optional fluorine substitution

Scheme 5



Scheme 6

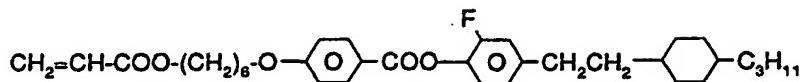


The following examples are intended to be illustrative but by no means limitative.

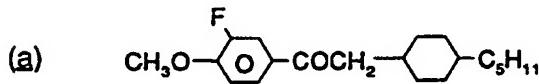
Example 1

5

Preparation of



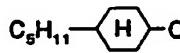
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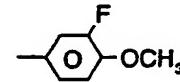


15

Quantities

20

230.5  100 g ≡ 3.0368 m

126  374 g ≡ 2.961 m

133.5 AlCl₃ 426 g ≡ 3.188 m

DCM 3.5 L

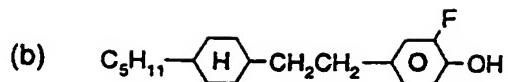
25

The AlCl₃, o-fluoroamide and DCM (2 l) were charged into a 10 l flask fitted with stirrer, dropping funnel and thermometer which was vented to a scrubber. This mixture was then cooled to 10 °C and the acid chloride in DCM (1-5 l) was added maintaining the temperature below 15 °C. On addition the mixture was allowed to achieve room temperature, with stirring, overnight. Checked by TLC. Slight amount of anesole remaining, insignificant. Reaction mixture poured onto ice, 1-5 kg and ice allowed to melt. Aqueous removed and extracted with DCM (3 x 500 ml). Organics combined and washed to neutral with water before drying over Na₂SO₄, filtering and evaporating to dryness. Crude, hot liquid then diluted with MS (21) and mixture heated, hot filtered and left to crystallize. Yield = 655 g

30

35

- 24 -



5	<chem>C5H11-C6H5-CH2CO-C6H2(F)(O)OCH3</chem> (a)	650 g	\equiv	2.03 moles
	Potassium hydroxide	162.5 g	\equiv	1/4 wts
	Hydrazine hydrate	715 mls	\equiv	1.1 v
10	Digol	3.757 l	\equiv	5.5 v

The starting materials were charged into a 20 l flange top flask sited on a mantle and fitted with an air stirred and reflux condenser. The mixture was then heated to ~138 °C and refluxed for two hours. The condenser was then rearranged and the mixture heated to 190 °C, collecting the distillate. The condenser was then changed back and the mixture stirred and refluxed for 20 hours. Sample taken out and checked by AC, reaction complete. Mixture poured onto ice (2 kg), acidified and extracted with DCM (3 x 1 l). Organics combined and washed to neutral with water. Dried, filtered and evaporated to dryness.

Analysis by GC showed that not only had the starting material been reduced by it had been totally demethylated as well.

Yield crude = 640 g (14 % by GC)

Distilled yield = 360 g

30

35

(c) Quantities

5 71 g $\text{CH}_2=\text{CHCO}_2-(\text{CH}_2)_6-\text{O}-$ -COOH (C.J. Broer et al.
Makromol.
Chem. (1989)
190, 2255)

0.1 ml dimethylformamide (DMF)

40 ml diethyl ether

2.7 ml SOCl_2

40 ml water

20 ml brine

0.022 mol Phenol (b)

15 40 ml DCM

4.6 ml triethylamine

To a mixture of 71 g hydroxyhexoxybenzoic acid (methacrylate ester) dimethylformamide and 40 ml of diethyl ether, through which a stream of nitrogen was bubbled, was added, over a period of 20 minutes 27 ml of SOCl_2 . After addition of the SOCl_2 stirring was continued for one hour until the mixture had become clear. The mixture was then poured onto 40 ml of water in a separating

25 funnel. After separation the ethereal layer was extracted with 20 ml of brine and dried over MgSO_4 . The ether was then evaporated at 90 °C using a rotor evaporator. The yield of acyl chloride was 8.17 g.

To 8.17 g of the acyl chloride was added 5.82 g of the phenol (0.022 mol) (b) 40 ml DCM and 46 ml triethylamine the reaction was left to mix initially in a cold bath for a period of 3 days.

35 The reaction was worked up by pouring into 1 ml HCl in 20 ml water. The aqueous layer was extracted with DCM. The DCM layers were then combined and washed with water and dried over anhydrous sodium sulphate.

The acide product was then columned on a silica column (60.7 g) and eluted with 5 % ethyl acetate in petrol 40-60 °C. The product being first preabsorbed onto 2 weights of silica.

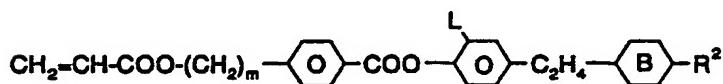
5 Results: Yield = 10.60 g (81.0 %)
 Purity = 95.58 % by HPLC

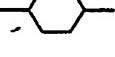
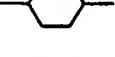
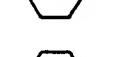
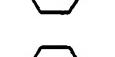
10 The product was then recrystallized from 4 volumes, yield 9.19, HPLC 99.7 %, of ethanol and dried overnight in the vacuum oven.

15 The product exhibits:

K 51.1 N 125.8 I

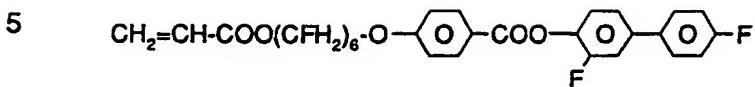
15 Analogously the following reactive compounds are obtained:



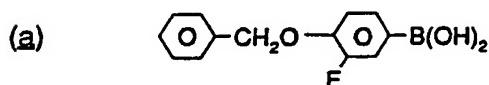
20	m	L		R ²
	4	F		C ₅ H ₁₁
25	6	F		C ₃ H ₇ K 54.9 N 124.5 I
	4	F		C ₃ H ₇
	6	H		C ₃ H ₇ K 47.0
30	4	H		C ₃ H ₇ K 54.9 N 124.5 I
	6	H		Cl K 85.8 S _A 104.6 N 119.8
35	4	H		Cl
	6	H		C ₃ H ₇ K 96.3 N 106.5 I
	4	H		C ₃ H ₇

Example 2

Preparation of



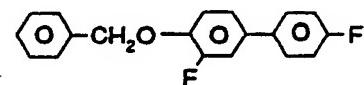
10



15

A solution of n-butyllithium (10.0 M in hexane, 3.30 ml) is added dropwise to a stirred solution of 3-fluoro-4-benzyl-bromobenzene (9.0 g) in THF (70 ml). The stirred solution is maintained under these conditions for 2.5 hrs and then a cooled solution of tri-isopropylborate (11.28 g) in dry THF (50 ml) is added.

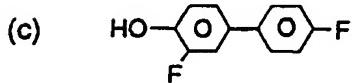
20



25

A solution of (2a) in ethanol is added to a stirred mixture of p-fluorobromobenzene and tetratros (triphenyl(phosphine)) palladium (O) in benzene and $2\text{M-Na}_2\text{CO}_3$ at room temperature. The stirred mixture is heated under reflux ($90\text{-}95^\circ\text{C}$) for 23 hrs. After usual work-up the solvent is removed in vacuo and the residue is used in the following steps without further purification.

30

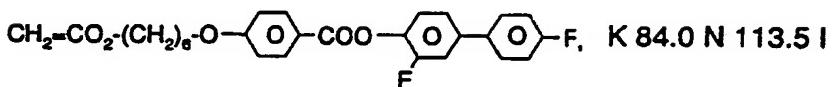


35

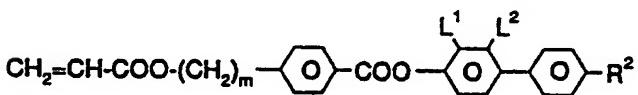
5 % Palladium-on-charcoal (4.0 g) is added to the benzylether 2b in toluene. The stirred mixture is hydrogenated at atmospheric pressure for 4 hrs and the mixture is filtered. After usual work-up the solvent is removed to afford 2c.

(d) The esterification with

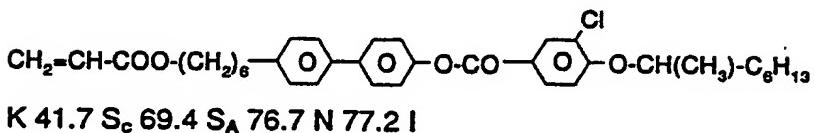
5 $\text{CH}_2=\text{CO}_2-(\text{CH}_2)_6-\text{O}-\text{C}_6\text{H}_4-\text{COOH}$ is carried out in analogy to example 1c and yields



Analogously the following reactive compounds are obtained:

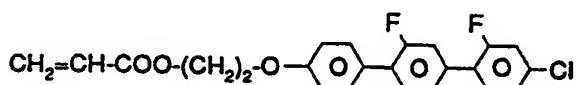


m	L ¹	L ²	R ²	
4	F	H	F	
6	H	F	F	K 86.8 N 110.8 I
4	H	F	F	
6	H	F	Cl	K 67.7 SA 90.7 N 131.7 I
4	H	F	Cl	
6	H	F	C ₃ H ₇	K74.2 SA 82.7 N 128.2 I
4	H	F	C ₃ H ₇	
20	6	H	C ₅ H ₁₁	
	4	H	C ₅ H ₁₁	

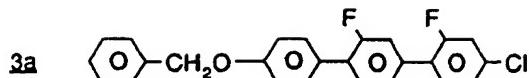


Example 3

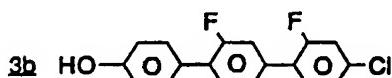
Preparation of



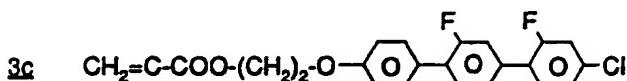
- 29 -



5 4'-Benzyl-2-fluorobiphenyl-4-ylboronic acid is obtained analogously to example 2a from 4'-benzyl-2-fluoro-4-bromobiphenyl and is reacted with 4-chloro-2-fluorobromobenzene as described in Example 2b.



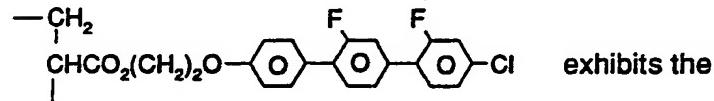
10 3a is hydrogenated analogously to the method described in Example 2c.



15 3b is reacted with oxirane in the presence of pyridine and esterified with acrylic acid in the presence of trifluoroacetic anhydride and dichloromethane 20 hrs at room temperature.

The resulting product shows K₁ 73 K₂ 83 I.

20 After polymerization the side-chain polymer of formula



25 following mesophases: Tg 53.8 N 181 I.

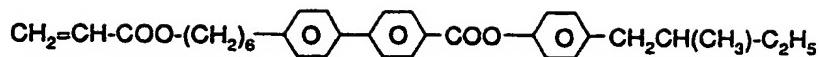
Example 4

30 The following compounds are obtained in analogy to Example 2d by esterification of the corresponding phenols with the corresponding benzoic acids:



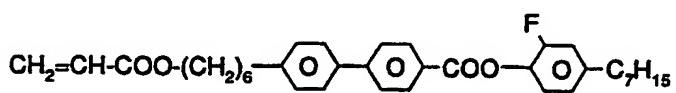
35 K 74.4 S_c 89.1 N 100.6 I

- 30 -



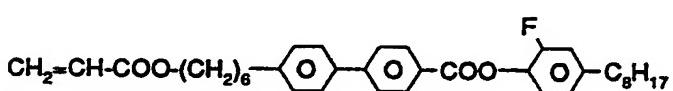
K 38.5 I

5



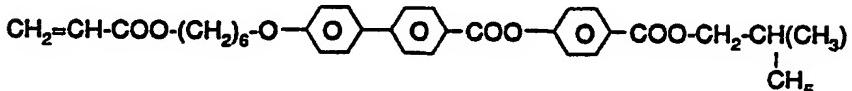
K 75.5 (S 65.4) N 170.2 I

10

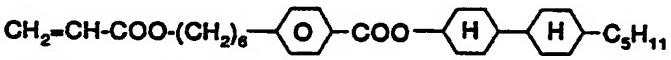


K 83.3 (S_c 84.6) N 158 I

15

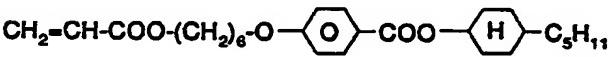


K 53.5 S_c 84.5 S_A 133.4 N 140 I



K 77 S 131 N 162 I

20



K 62.4 (N 32) I

25

30

35

PATENT CLAIMS

1. Liquid crystalline copolymer obtainable by copolymerization of at least one polymerizable reactive component A of formula I

5



wherein

10

R1 is $CH_2=CW-COO-$, $HWC-C-$, $HWN-$, $CH_2=CH-$ or $HS-CH_2-(CH_2)_m-COO-$ with W being H, Cl or alkyl with 1-5 C atoms and m being 1-7

15

P is alkylene with up to 12 C atoms, it being also possible for one or more non adjacent CH₂ groups to be replaced by -O-,

20

X is -O-, -S-, -COO-, -OCO-, -C≡C- or a single bond,

25

R₂ is a straight-chained, branched or chiral alkyl radical with up to 15 C atoms which is unsubstituted, mono- or polysubstituted by halogen, it being also possible for one or more CH₂ groups in these radicals to be replaced, in each case independently of one another; by -O-, -S-, -CO-, -OCO-, -CO-O- or -O-CO-O- in such a manner that oxygen atoms are not linked directly to one another, or alternatively R₂ has one of the meanings given for R¹-P-X-,

30

35

- 32 -

A1 is a 1,4-cyclohexylene, a 1,4-phenylene in which one or two CH groups may be replaced by N or a naphthalene-2,6-diyl radical which is unsubstituted or substituted by 1 to 4 halogen atoms,

5



10

with and being or

it being possible for these rings to be substituted by CN or halogen and one of the 1,4-phenylene groups can also be replaced by a 1,4-phenylene radical in which one or two CH groups are replaced by N,

15

and

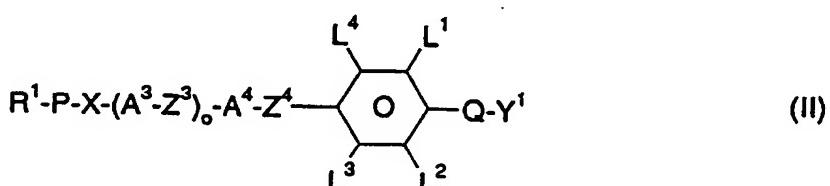
Z¹ and Z² are each independently -CO-O-, -O-CO-, -CH₂CH₂-, -C≡C- or a single bond,

20

n is 0 or 1,

and at least one polymerizable component B of formula II

25



30

wherein R¹, P, X and the meaning give for formula I, and Q has the meaning given for formula I, and

Y¹ is -H, -F or -Cl,

35

Q is -CF₂, -OCF₂, -C₂F₄, or -OC₂F₄, or a single bond, if Y¹ is F or Cl

A^3 and A^4 are each independently

(c) 1,4-phenylene radical in which one or two CH groups can be replaced by N,

5 (d) a 1,4 cyclohexylene radical in which one or two non-adjacent CH₂ groups can be replaced by -O- or -S-, or

10 (e) a naphthalene-2,6-diyl radical, a piperidine-1,4-diyl radical, a thiophene-2,5-diyl radical, a 1,3,4 thiadiazol-2,5-diyl radical, it being possible for radicals (c) and (d) to be substituted by CN or halogen,

15 Z^3 is, independently of one another, -CH₂CH₂- , -COO- , -OCO- , -C≡C- or a single bond,

20 Z^4 is -CH₂CH₂- , -C≡C- or a single bond,

L¹ through L⁴ are each independently H, halogen, -CH₃, -CF₃ or -CN, preferably

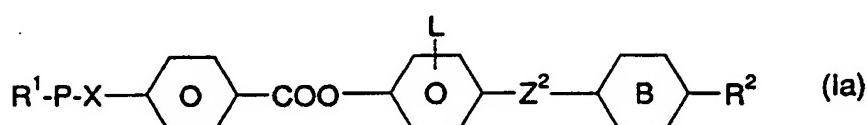
25 H or fluorine.

o is 0, 1 or 2, and

the groups A^3 being same or different in the case that o is 2.

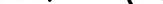
25 2. Polymerizable, reactive liquid crystal compound of formulae I or II, wherein X is -C≡C-.

30 3. Polymerizable, reactive liquid crystal compound of formula Ia



35 wherein R¹, R², P, —B— and X have the meaning given, and

Z^2 is $-\text{CH}_2\text{CH}_2-$ or a single bond, preferably $-\text{CH}_2\text{CH}_2-$

5  denotes  ,  or  .

4. Polymerizable, reactive liquid crystal compound of formula Ib

10

(Ib)

wherein R₁, R₂, P, —  — and X have the meaning given, and

Z^2 is $-\text{CH}_2\text{-CH}_2-$ or a single bond, or in the case that L° is Cl Z^2 denotes also $-\text{O-}\text{CO}-$.

20  denotes a 4,4'-biphenyldiyI group being optionally substituted by p fluorine or chlorine atoms, and

25 p is 0 or an integer between 1 and 4.

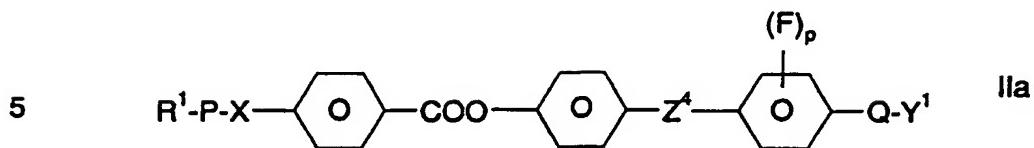
5. Polymerizable reactive liquid crystal compound according to one of the claims 2 to 4 wherein R₂ is achiral.

30 6. Polymerizable reactive liquid crystal compound of formula II,
wherein

Q-Y1 is F, Cl, -OCF₃, -OCF₂H, -CF₃ or OC₂F₅.

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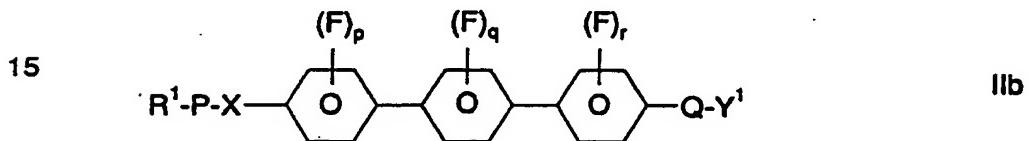
7. Polymerizable reactive liquid crystal compound of formula IIa



wherein R¹, P, X, Q, Y¹ and p have the meaning given and

10 Z^4 is - CH_2CH_2 of a single bond.

8. Polymerizable reactive liquid crystal compound of formula IIb



wherein R¹, P, X, Q, Y¹ and p have the meaning given and q and r are each independently 0 or an integer selected from 1 to 4.

9. Polymerizable reactive liquid crystal compound according to one of the claims 2 to 8, wherein

25 R¹ is CH₂=CW-COO-

with W being H, Cl or CH_3 .

30 10. Liquid crystalline polymer obtainable by polymerization of at least one polymerizable reactive liquid crystal compound according to the Claims 2 to 9.

35 11. Liquid crystalline polymer obtainable by substance photo-polymerization of at least one polymerizable reactive liquid crystal compound of formulae I or II, in the presence of a photoinitiator, at least one of said reactive liquid crystal compounds being oriented in its liquid crystalline phase.

12. Liquid crystalline polymer according to claim 11, characterized in that the reactive liquid crystal compound is oriented in its nematic phase.
- 5 13. Liquid crystalline (co-)polymer according to one of the claims 9 to 12, obtainable by polymerization in the presence of a plasticizer, preferably a dialkylphthalate, and/or a chiral dopant, preferably a chiral cyanobiphenyl, phenyl benzoate, menthol or lactic acid derivative.
- 10 14. Use of a liquid crystalline copolymer according to Claim 1 in the field of integrated optics, opto-electronic and/or information storage.
- 15 15. Use of a liquid crystalline polymer according to one of the claims 9-13 in the field of integrated optics and/or opto-electronic.

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Patents Act 1977
 Examiner's report to the Comptroller under Section 17
 (The Search report)

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Relevant Technical Fields		Search Examiner A KERRY
(i) UK Cl (Ed.N)	C3P: PDF, PDZ	
(ii) Int Cl (Ed.6)	C09K 19/38	Date of completion of Search 24 OCTOBER 1994
Databases (see below)		Documents considered relevant following a search in respect of Claims :- 1-15
(ii) ONLINE DATABASES : CAS ONLINE		

Categories of documents

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Category	Identity of document and relevant passages		Relevant to claim(s)
X	GB 2257432 A	(SECRETARY OF STATE FOR DEFENCE) - see Claims 1-8, Examples	3-5, 9-11
X	GB 2240548 A	(CIBA GEIGY) - see Claim 1, Examples	6, 9-11
X	GB 2185487	(GEC) - see Figure 2, page 2 line 45	4-5, 9-11
X	EP 0412485 A1	(CANON KK) - see Claim 1, Examples	6, 9-11
X	EP 0228703 A2	(IDEMITSU KOSAN) - see Claim 1, Examples	9-11
X	WO 91/19773 A1	(MMM) - see Claim 1, Examples	6, 9-11

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